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THE DESIGN ENHANCEMENT AND ANALYSIS OF TWO WHEELER SUSPENSION COIL SPRING

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ABSTRACT

A suspension system or shock absorber is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy. The shock absorbers duty is to absorb or dissipate energy. In a vehicle, it reduces the effect of travelling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduced amplitude of disturbances. The design of spring in suspension system is very important. In this paper the design and analysis of a shock absorber coil spring is presented. 3D models are created using CATIA drafting package. The models are designed according to variation of the pitch of the spring and compared with the original dimensions of the spring. Static Structural analysis and Modal analysis are performed on the designed models of shock absorber by varying materials for the spring. The analysis is done by considering loads like bike weight, 1 person and 2 persons. The designed models and materials were compared to obtain best model and best material for coil spring in Shock absorber.

KEYWORDS: Dual Rate Spring, Linear Rate Spring, Suspension Coil Spring, Static Structural Analysis, Modal Analysis, Materials, Catia & Ansys

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Original Article

1. INTRODUCTION

The shock absorber which is one of the suspension systems is designed mechanically to handle shock impulse and dissipate kinetic energy. It reduces the amplitude of disturbances leading to increase in comfort and improved ride quality. Hence, the designing of spring in a suspension system is very crucial.

A spring is defined as an elastic body, whose function is to deform when loaded and to recover its original shape when the load is removed. It is an elastic body used to store mechanical energy. When a spring is compressed or stretched, the force it exerts is proportional to its change in length.

Prince Jerome Christopher J and Pavendhan R [1]designed a shock absorber used in 160 cc bike and modelled in Pro/engineer software. The model was designed by modifying the wire diameter and stress analysis and deformational analysis is performed. The materials used in this model were spring steel ASTM A227 grade. The spring was analyzed in ANSYS software for the stress analysis and deformational analysis. The stress value was lesser in their designed spring than in the original. By comparing the results it was observed that the modified spring has reduced weight and it was safe.

Raviraj N. Rathod and Milind S. Bodkhe[2] analyzed the spring with materials like Beryllium copper and Oil tempered spring steel and performed total deformation and Equivalent shear stress by using Ansys Software. Beryllium Copper was found as the safer material for the maximum loading as compared to oil tempered spring steel.

Mallick Kamran and Maner Abdullah[3]designed a spring witha varied wire diameterwith high carbon spring steel as the material. They have performed the Finite Element Analysis for the 3 models designed and also performed the analysis in Ansys. Then both the results of total deformation and von-Mises stress are both compared at different load conditions in the form of graphical representation and tabular format they have observed that the design with wire diameter reduction have given best results compared to the other two results.

N. Lavanya, P. Sampath Rao and M. Pramod Reddy[4]experimented on two materials for designing the spring-low carbon-structural steel and chrome vanadium steel. The analysis is performed with the materials mentioned for the model and the static analysis, stress and strain analysis is performed and finally they have concluded that low carbon-structural steel yields the best results compared to chrome vanadium steel.

T. R Sydanna and Chittetu Maheswara Reddy [5]carried out their work on modelling, analysis and testing of suspension spring is to replace by different material. The models were designed for three different models of the bikes and by applying two material alloy steel and chromium vanadium steel analysis is carried out in ANSYS. The analysis was performed at different load conditions and maximum shear stress, maximum principle stress, normal stress, strain, max principal strain, normal strain and total deformation are noted and compared. It was concluded that alloy steel is preferable compared to chromium vanadium steel.

2. PROBLEM DEFINITION

- Study the existing design of helical spring of two wheeler (i. e., splendor 125cc bike).
- Model the existing design of spring in CATIA software and carry out analysis in ansys.
- Vary the pitch of the spring and model two different springs with same wire diameter.
- Analyze the new designs in ANSYS Workbench and prepare two different designs.

Nominate the optimized design of spring for two wheeler.

3. MATHEMATICAL CALCULATIONS

3.1 Dimensions of Baseline Model of a Spring

Mean coil diameter = 46.5mm

Outer diameter = 50mm

Inner diameter = 43mm

Wire diameter = 7mm

No. of active coils = 17

Total no. of coils = 19

Pitch of the spring = 10 and 15mm

Weight of the bike = 110kg

3.2 Load Calculations

Weight of the bike (w1) = 110kg

Average weight of 1 person (w2)= 70kg

Average weight of 2 persons (w3) = 140kg

Weight of bike + 2 persons (w4) = 250kg = 2452.5N

Rear suspension (w5) = 65% of total weight = 65% of 250kg = 162.5kg

Considering the dynamic loads on the spring = 2*w5 = 2*162.5 = 325kgs = 3188.25N

For single shock absorber weight = $\frac{w}{2} = \frac{3188.25}{2}$ =1594.125 ≈ 1600N

Weight according to the bike weight = 701N

Weight according to bike weight and 1 person = 1150N

Weight according to bike weight and 2 person = 1600N

3.3 Theoretical Calculations for Spring Design

Spring Index = C = $\frac{D}{d} = \frac{46.5}{7}$ = 6.643mm

Shear stress factor (k_s) = $1+\frac{1}{2C} = 1+\frac{1}{2*6.643}$ = 1.075

Wahl's correction factor (k_w) = $\frac{4C-1}{4C-4} + \frac{0.615}{C} = \frac{4*6.643-1}{4*6.643-4} + \frac{0.615}{6.643}$ = 1.225

At load = 701N

Maximum shear stress induced in the wire (τ) = $k_s * \frac{8wD}{\pi*d^3}$ = $1.075*\frac{8*701*46.5}{\pi*7^3}$ = 260.15Mpa

Deflection (δ) = $\frac{8WD^3n}{G*d^4} = \frac{8*701*46.5^3*17}{119*7^4}$ = 33.548mm

At load = 1150N

Maximum shear stress induced in the wire (τ) = $k_s * \frac{8wD}{\pi*d^3}$ = $1.075*\frac{8*1150*46.5}{\pi*7^3}$ = 426.78Mpa

Deflection (δ) = $\frac{8WD^3n}{G*d^4} = \frac{8*1150*46.5^3*17}{119*7^4}$ = 55.037mm

At load = 1600N

Maximum shear stress induced in the wire (τ) = $k_s * \frac{8wD}{\pi*d^3}$ = $1.075*\frac{8*1600*46.5}{\pi*7^3}$ = 593.8Mpa

Deflection (δ) = $\frac{8WD^3n}{G*d^4} = \frac{8*1600*46.5^3*17}{119*7^4}$ = 76.57mm

Solid length (L_s) = n*d = 17*7 =119mm

4. MATERIALS AND MECHANICAL PROPERTIES

Various materials like Molybdenum, Nickel chrome alloy, Chrome Vanadium are chosen and the material properties are as follows

Table 1: Material and Properties

Material & Properties	Molybdenum	Nickel Chrome	Chrome Vanadium
Density (kg/m^3)	10.03	8.65	7.8
Young’s Modulus (Gpa)	330	245	190
Shear modulus(Gpa)	119	100	73
Poisson ratio	0.38	0.325	0.29
Tensile yield strength(Mpa)	324	245	420

5. TYPES OF COIL SPRINGS

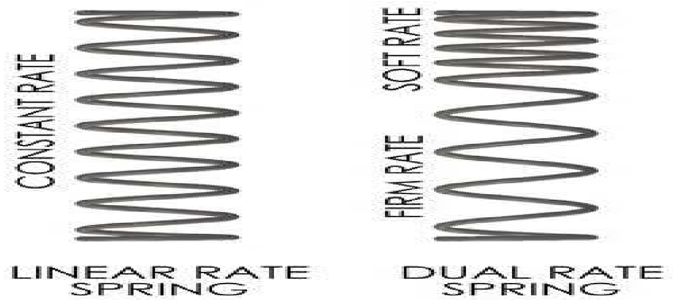

Figure 1: Two Different Coil Springs

5.1 Designed Models of Coil Springs in CATIA

There are three types of coil springs designed in CATIA.

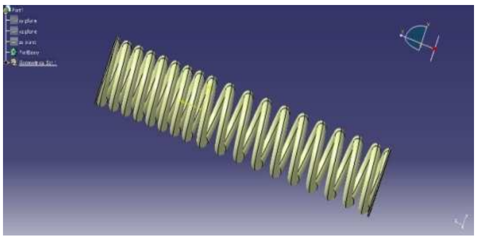

Figure 2: Dual Rate Spring

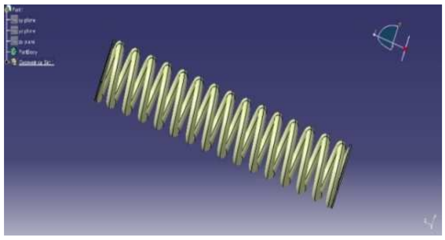

Figure 3: Linear Rate Spring

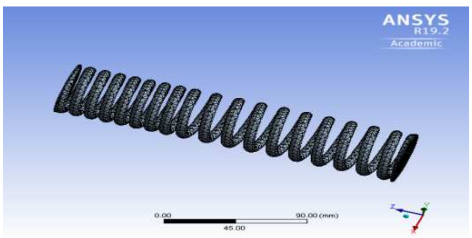

Figure 4: Meshed part in Ansys Workbench

5.2 Boundary Conditions for the Model

- Fixed support at one end A
- Force applied at other end B

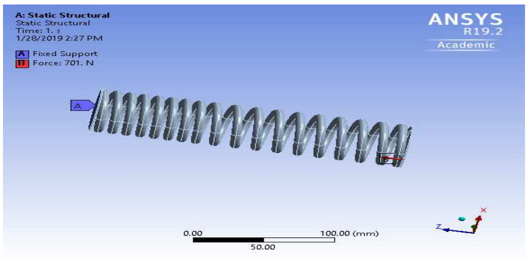

Figure 5: Defining Fixed Support and Load Applied Direction

6. STATIC STRUCTURAL ANALYSIS

Structural analysis is the most common application of the finite element method as it implies bridges and buildings, naval, aeronautical and mechanical structures such as ship hulls, aircraft bodies and machine housings as well as mechanical components such as pistons, machine parts and tools.

Static analysis used to determine displacements, stresses etc. under static loading conditions. Ansys can compute both linear and nonlinear static analysis. Nonlinearities can include plasticity, stress stiffening large deflection, large strain, hyper elasticity, contact surfaces and creep.

6.1 Dual Rate Spring

In this dual rate spring analysis we have performed static structural analysis by considering 3 different load conditions on dual rate spring. We got the less deformation values of molybdenum, nickel chrome alloy, chrome vanadium. Among these materials we got best values to the molybdenum and the equivalent stress are more, compared to other two materials in all the load conditions.

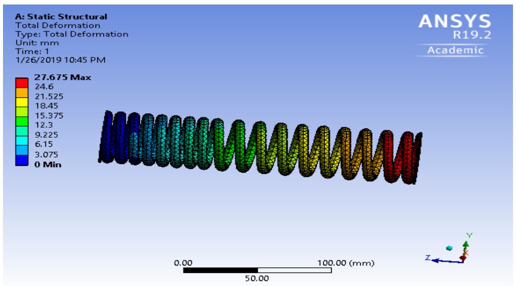

Figure 6: Total Deformation

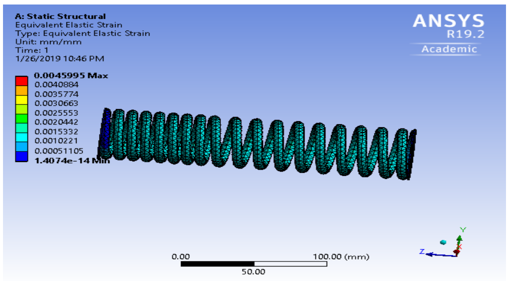

Figure 7: Equivalent Elastic Strain

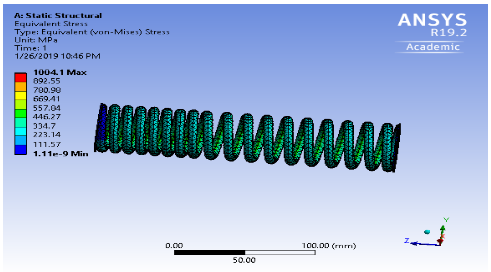

Figure 8: Equivalent Stress

Table 2: Analysis Results at Load (W) =701N

Material	Total Deformation (mm)	Equivalent Elastic Strain (mm/mm)	Equivalent Stress (Mpa)
Molybdenum	27.675	0.0045995	1004.1
Nickel chrome alloy	35.878	0.0060491	973.91
Chrome Vanadium	43.456	0.0045993	609.89

Table 3: Analysis Results at Load (W)=1150N

Material	Total Deformation(mm)	Equivalent Elastic Strain(mm/mm)	Equivalent Stress(Mpa)
Molybdenum	45.401	0.0075455	1647.3
Nickel chrome alloy	58.858	0.0099237	1597.7
Chrome Vanadium	71.291	0.0075452	1000.5

Table 4: Analysis Results at Load (W)= 1600N

Material	Total Deformation (mm)	Equivalent Elastic Strain (mm/mm)	Equivalent Stress (Mpa)
Molybdenum	63.167	0.010498	2291.8
Nickel chrome alloy	81.89	0.013807	2222.9
Chrome Vanadium	99.187	0.010498	1392

6.2 Linear Rate Spring

In Linear rate spring analysis, static structural analysis has been done by considering three different load conditions on dual rate spring. Lower deformation values were obtained for molybdenum, nickel chrome alloy, chrome vanadium. Among these materials molybdenum is found to have less deformation and the equivalent stress is more, compared to other two materials in all the load conditions.

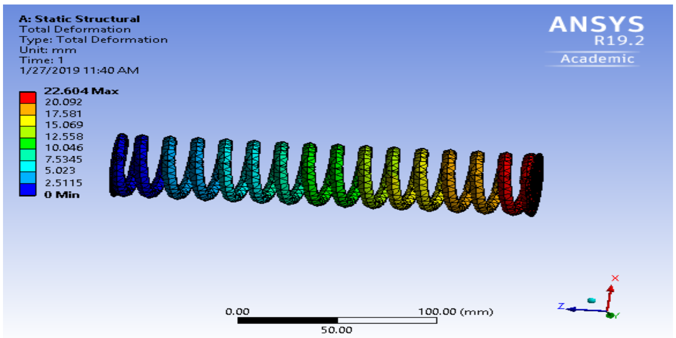

Figure 9: Total Deformation

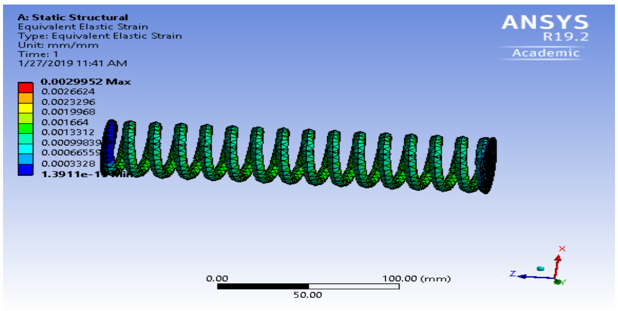

Figure 10: Equivalent Elastic Strain

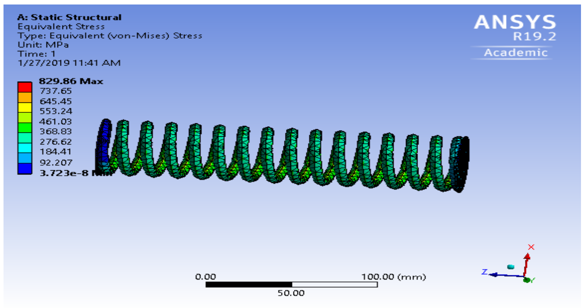

Figure 11: Equivalent Strain

Table 5: Analysis Results at Load (W) = 701N

Material	Total Deformation (mm)	Equivalent Elastic Strain (mm/mm)	Equivalent Stress (Mpa)
Molybdenum	22.604	0.0029952	829.80
Nickel chrome alloy	29.293	0.0042863	790.62
Chrome Vanadium	36.862	0.0056787	760.32

Table 6: Analysis Results at Load (W)= 1150N

Material	Total Deformation (mm)	Equivalent Elastic Strain (mm/mm)	Equivalent Stress (Mpa)
Molybdenum	37.081	0.0049136	1361.4
Nickel chrome alloy	48.056	0.0070317	1297
Chrome Vanadium	60.473	0.0093159	1247.3

Table 7: Analysis Results at Load (W)= 1600N

Material	Total Deformation (mm)	Equivalent Elastic Strain (mm/mm)	Equivalent Stress(Mpa)
Molybdenum	51.592	0.0068363	1894.1
Nickel chrome alloy	66.86	0.0097832	1804.6
Chrome Vanadium	84.136	0.012961	1735.4

7. MODAL ANALYSIS

A modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as harmonic response or full transient dynamic analysis.

Modal analysis, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

7.1 Dual Rate Spring

In this case, the analysis is performed at ideal conditions. The solutions for respective frequencies are obtained by the solver. The total deformation values were obtained based on these frequency values. The best results are obtained for the molybdenum as compared to other two materials. It can be observed that the material with higher frequency values can absorb the vibrations efficiently.

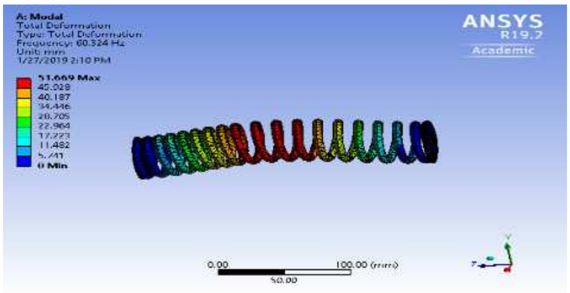

Figure 12: Total Deformation 1

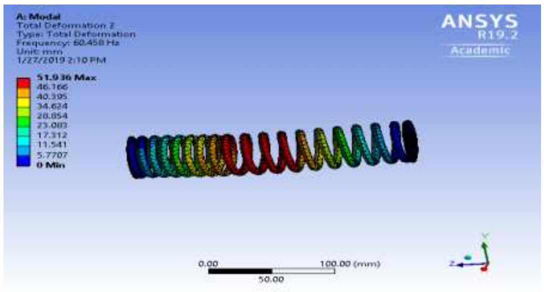

Figure 13: Total Deformation 2

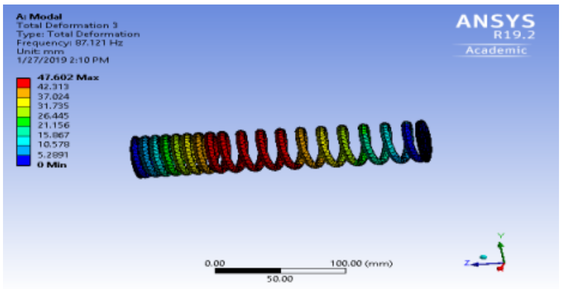

Figure 14: Total Deformation 3

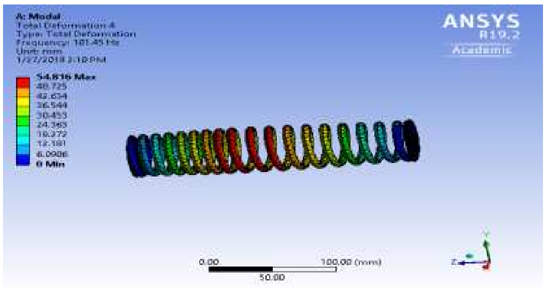

Figure 15: Total Deformation 4

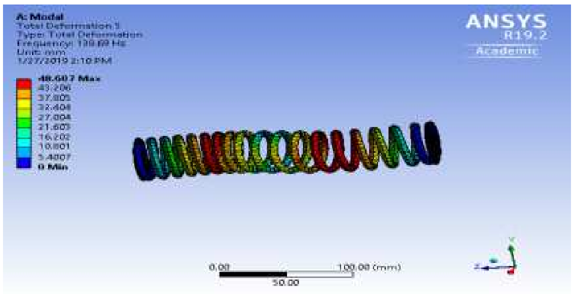

Figure 16: Total Deformation 5

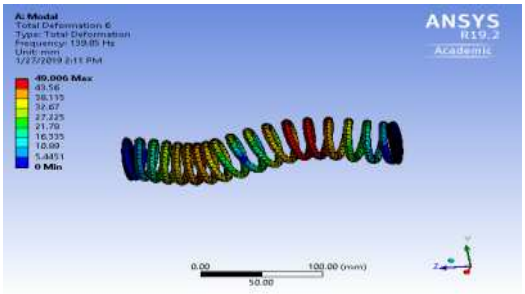

Figure 17: Total Deformation 6

Table 8: Modal Results for Dual Rate Spring

Material		Mode1	Mode2	Mode3	Mode4	Mode5	Mode6
Molybdenum	Frequency(hz)	60.324	60.458	87.121	101.45	138.69	48.609
	Total Deformation(mm)	51.669	51.936	47.602	54.816	48.609	49.006
Nickel Chrome Alloy	Frequency (hz)	57.121	57.233	83.469	94.967	131.15	131.51
	Total Deformation(mm)	56.368	56.687	51.953	59.831	53.151	53.45
Chrome Vanadium	Frequency (hz)	53.246	53.336	78.392	87.902	122.14	122.5
	Total Deformation(mm)	59.351	59.703	54.72	63.017	56.038	56.272

7.2 Linear Rate Spring

In case of linear rate springs also, the best results are obtained for the molybdenum as compared to other two materials. The results are graphically represented in figures 18 to 23.

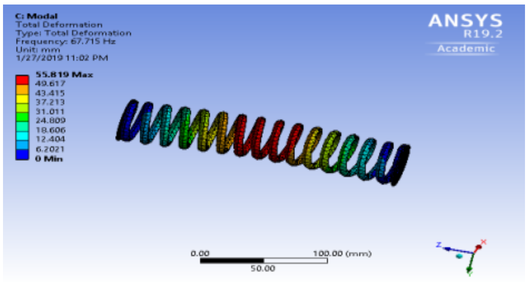

Figure 18 Total Deformation 1

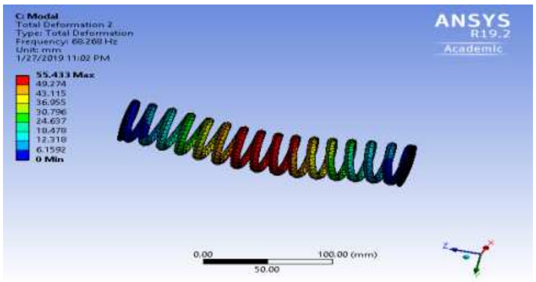

Figure 19 Total Deformation 2

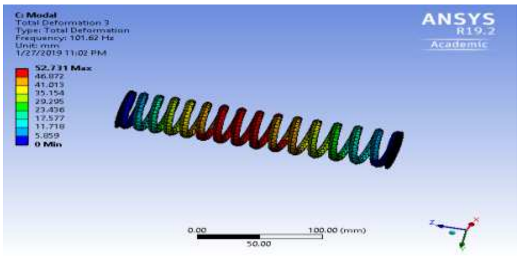

Figure 20 Total Deformation 3

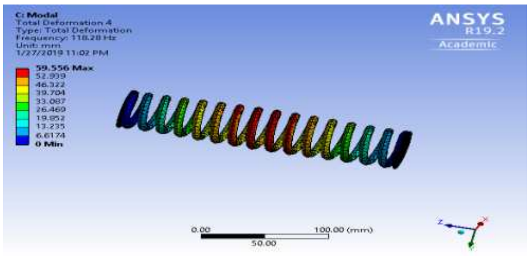

Figure 21 Total Deformation 4

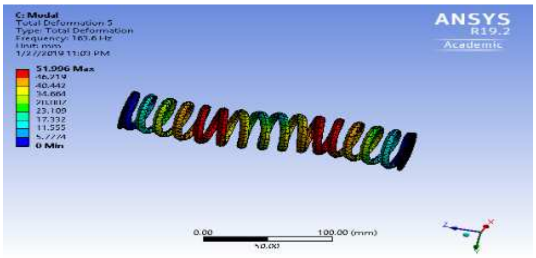

Figure 22 Total Deformation 5

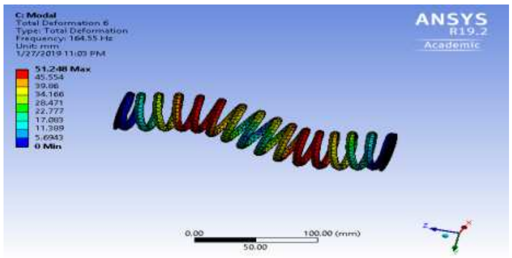

Figure 23 Total Deformation 6

Table 9: Modal Results for Linear Rate Spring

Material		Mode1	Mode2	Mode3	Mode4	Mode5	Mode6
Molybdenum	Frequency(hz)	67.715	68.262	101.62	118.28	163.6	164.55
	Total Deformation(mm)	55.819	55.433	52.731	59.556	51.996	51.248
Nickel Chrome Alloy	Frequency (hz)	64.14	64.628	97.377	110.73	154.78	155.59
	Total Deformation(mm)	60.907	60.464	57.519	65.018	56.77	55.878
Chrome Vanadium	Frequency (hz)	59.799	60.232	91.462	102.5	144.19	144.9
	Total Deformation(mm)	64.141	63.661	60.559	68.493	59.813	58.822

8 RESULTS AND CONCLUSIONS

In this suspension coil spring, two different models like dual rate and linear rate springs were designed and three different materials like molybdenum, nickel chrome alloy, chrome vanadium were used with three different load conditions. Among the three materials with two different models linear rate spring and molybdenum give the better deformation and stress values at each preferred load conditions comparing to other model and materials. Molybdenum material is to be preferred for bike suspension spring due to its material stability and ductility by observing the results of static structural and modal analysis. Therefore, from the above practical results linear rate spring made with molybdenumis found to give good efficiency compared to others and can suit for high load conditions.

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